Status of the Demersal Fishery Resources of Bangladesh

Md. Ali Azam Khan, Nasir Uddin Sada and Zubair Ahmed Chowdhury
Marine Fisheries Survey
Department of Fisheries
Chittagong 4100, Bangladesh

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Abstract

The present study makes use of the fisheries survey data collected during the period 1984 - 87 by the multi-purpose research vessel RV Anusandhani in the waters of Bangladesh, Bay of Bengal. The data consists of twelve survey cruises directed at the shrimp resources (1985 - 87) and nineteen survey cruises directed at the demersal fish resources (1984 - 86).

The biomasses for shrimp and demersal fish during the survey period were estimated, along with a detailed analysis of biomass distribution by depth zone and catch rates for important species of shrimp and demersal fish species. The demersal fish and shrimp biomass during the survey period was estimated as 176 160 t and 857 t, respectively. The levels of biomass when compared with 1973 estimates indicate a tremendous decline, by about 90% for shrimps and 30% for demersal fish.

Population parameters for four species of shrimps (for both males and females) as well as for eight demersal fish species were also estimated. The parameter estimates were validated using available growth and mortality parameter values from the literature, and were in turn used to estimate the mean exploitation rate (E) of demersal fish and shrimp species comprising the trawl catch. Mean E values for shrimp species is at 0.61 and 0.57 for demersal fish species, indicating over-exploitation of demersal resources in the Bay of Bengal.

Exploratory analysis using surplus production modeling of catch and effort data shows that the maximum sustainable yield (MSY) level for shrimp resources is around 3 500 t, corresponding to a maximum effort level of approximately 6 480 fishing days. Similar analysis for demersal fish catches gave poor correlations between catch rates and fishing effort.

Introduction

The 200 nm Exclusive Economic Zone (EEZ) of Bangladesh encloses an area of about 166 000 km^2 while the length of its coastline from the southeast border to the southwest border is approximately 710 km. The continental shelf, covering an area of 66 440 km^2, is relatively shallow with about 36% (24 000 km^2) less than 10 m deep (Table 1). The shelf area down to about 150 m depth appears to be very even, although some areas with obstacles hazardous to trawling have been observed. The continental edge is found at depths between 160 to 180 m.

The continental slope is very abrupt making demersal trawling operations impractical, particularly in waters deeper than 180 m (Khan et al. 1997). The continental shelf within the 50 m depth zone contains significant fish resources, however, factors such as salinity, dissolved oxygen and water temperature tend to limit the distribution of fish to a narrow belt, so that the effective fishing area is reduced to about 14 000 km^2. The marine shrimp grounds are further restricted to only about 700 km^2 (Rahman 1992). The major species groups targeted by trawls in the coastal waters of Bangladesh are the penaeid prawns and several species of demersal fish.

Table 1. Depth distribution of shelf areas of Bangladesh waters.

Depth Zone (m)	Area (km^2)	%
Up to 10	24 000	36
10 - 24	8 400	13
25 - 49	4 800	7
50 - 74	5 580	8
75 - 99	13 410	20
100 - 199	10 250	16
TOTAL	66 440	100

The annual marine fish production of Bangladesh in 1996 - 97 was about 274 704 t, about 95% (261 140 t) of which was contributed by coastal (artisanal) fisheries. The annual trends in fish production during 1990 - 99 are given in Table 2. There was an increase in the total marine production from 241 538 t in 1990 - 91 to about 291 900 t in 1998 - 99. Marine shrimp landings during this period almost doubled and the catches were mostly from artisanal gear.

Since 1958 several resource surveys have been conducted in Bangladesh, particularly to assess the status of the demersal fish resources. Results of these surveys showed great variation in the estimates of demersal fish stock ranging from 55 000 t to 373 000 t. Significant work has been carried out by Khan et al. (1983); Lamboeuf (1987); Penn (1982); Saetre (1981); West (1973). Amongst them, Lamboeuf (1987) estimated the standing stock of demersal fish at 157 000 t within the 10 to 100 m depth zone, and about 188 000 t within the 10 - 200 m depth area. These estimates are based on 17 cruises covering 581 stations in the Bangladesh waters of the Bay of Bengal. Although the trawl surveys do not cover the same number of cruises as that of Lamboeuf (1987); Saetre (1981) estimated the standing stock of demersal fish at 160 000 t, while Khan et al. (1983) estimated it at 152 000 t.

Previous surveys have been conducted principally to estimate the resource potential of fish stocks. The most comprehensive of these (mainly trawling) were the ones under the UNSF/PAK-22 Project conducted from 1968 - 71 by the Bangladesh Fisheries Development Corporation (BFDC), in collaboration with Food and Agriculture Organization (FAO). The project covered an area of 26 000 km^2 and resulted in the identification and charting of four major commercial fishing grounds. These are South Patches (3 662 km^2), Southwest of South Patches (2 538 km^2), Middle Ground (4 600 km^2) and "Swatch of No Ground" (3 800 km^2) (Fig. 1).

Until the beginning of 1984, trawl survey cruises were conducted by foreign government agencies and a few international organizations for the purpose of demersal fish stock assessment. During the period from 1984 to 1987, the research vessel RV Anusandhani was placed under the operational control of the FAO/UNDP Project BGD/80/025. Foreign marine scientists worked on board the vessel along with counterparts from the Department of Fisheries, Bangladesh. The surveys were carried out to provide biological information and reliable assessments of major fish stocks in order to implement rational fisheries management schemes and well-defined policies.

This study aims to provide an overview of the status of demersal fish stocks in the waters of Bangladesh, Bay of Bengal. Biomass levels of commercially important species of fish and shrimps from the trawl surveys carried out using RV Anusandhani from 1984 - 87 are presented. It also infers the extent of over-fishing of the demersal resources by comparing the biomass and CPUE levels with earlier estimates. The growth and mortality parameters of some fish and shrimp species are also used to estimate the current level of exploitation.

Table 2. Fishery production of Bangladesh (1990 - 99).

Year	Total fish Production (t) (Inland + Marine)	Total Marine Production (t) (Fish + Shrimp)	Industrial Production (t) (Fish + Shrimp)	Artisanal Production (t) (Fish + Shrimp)	Marine Shrimp Production (t) (Trawl + Artisanal)	Marine Fish Production (t) (Trawl + Artisanal)
1990 - 91	895 935	241 538	8 760	232 778	17 633	223 905
1991 - 92	952 079	245 474	9 623	235 851	20 042	225 432
1992 - 93	1 020 654	250 492	12 227	238 265	23 975	226 517
1993 - 94	1 090 610	253 044	12 454	240 590	21 519	231 525
1994 - 95	1 172 868	264 650	11 715	252 935	20 360	244 287
1995 - 96	1 257 940	269 702	11 959	257 743	26 353	243 349
1996 - 97	1 306 739	274 704	13 564	261 140	24 818	249 886
1997 - 98	1 473 673	283 673	15 673	268 000	* 25 318	* 258 355
1998 - 99	1 598 900	291 900	15 900	276 000	* 26 020	* 265 880

Source: Banik and Humayun (1999); Department of Fisheries (DOF) (1999).
Note: * Approximate values

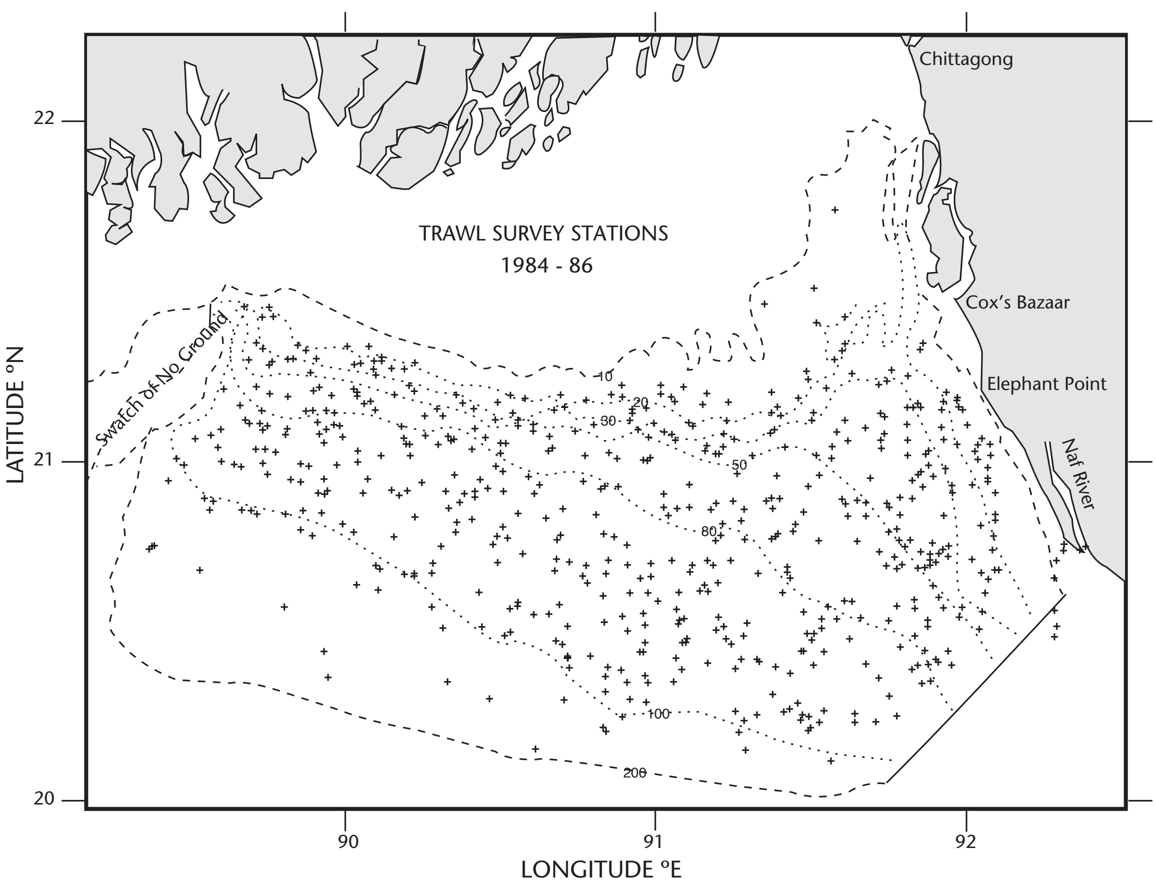

Fig. 1. The coastal waters of Bangladesh, Bay of Bengal and the trawl survey stations (1984 - 86) used for biomass estimation.

Materials and Methods

Estimation of Demersal Biomass

Data collected within the 10 - 100 m depth zone by RV Anusandhani in the Bay of Bengal off Bangladesh from September 1984 to October 1987 were used in the estimation of biomass of the demersal resources. RV Anusandhani is a multipurpose research vessel constructed in Japan in 1979 and designed mainly for stern trawling. The vessel has an overall length (LOA) of 32.4 m and a displacement of 221 GRT.

Fish trawling was conducted using a high opening Engel trawl with a cod-end mesh size of 32 mm and a head-rope length of 57.7 m. For shrimp trawling, a total of four nets were used. On each side of the vessel, twin shrimp nets of the same dimensions were operated from outriggers. Each had a head rope measuring 15.2 m in length while the ground rope was 18.6 m long. The total length of the net from the tip of the wing to the tip of the cod-end was 16.6 m. Detailed specifications of the research vessel and trawl nets are given in Lamboeuf (1987).

A total of 31 cruises were carried during the survey period (Table 3). Twelve (12) of these cruises were shrimp surveys while the remaining nineteen (19) were fish surveys. Fig. 1 shows an outline of the survey area indicating the location of trawling stations.

The survey area was limited towards the north and the east by the 10 m depth contour, as trawling and navigation in shallower waters were impossible due to the presence of artisanal fishers. The southern limit was originally set at the 200 m depth zone, but then only a few stations were actually undertaken beyond 120 m. A line drawn at 45º from the southern end of St. Martin's island towards Myanmar was taken as the limit of the survey area in the southeast. In the west, the limit was the eastern edge of the "Swatch of No Ground" fishing area.

On board catch sampling followed the procedures given in Pauly (1983). The catch was sorted and classified to species level whenever possible and separately weighed to the nearest 0.25 kg. In the event that a catch in a particular trawl haul exceeded 500 kg, a sub-sample was taken and the results were later raised to the value for the total catch. For large fish (whose number was usually

Table 3. List of RV Anusandhani trawl survey cruises (1984 - 87).

Cruise No.	Duration	Survey Type	Valid hauls
1	15 - 25 September 1984	Fish	42
2	3 - 13 October 1984	Fish	45
3	20 - 30 October 1984	Fish	43
4	9 - 19 November 1984	Fish	44
5	27 November - 5 December 1984	Fish	40
6	13 - 20 December 1984	Fish	41
7	24 - 28 December 1984	Fish	–
8	6 - 16 January 1985	Fish	46
9	31 January - 24 February 1985	Fish	49
10	17 - 24 February 1985	Fish	44
12	19 - 24 May 1985	Fish	13
13	12 - 17 July 1985	Fish	13
14	21 - 24 August 1985	Shrimp/Fish	7
15	28 September - 6 October 1985	Fish	29
16	22 - 31 December 1985	Shrimp	35
17	21 - 30 November 1985	Shrimp	26
18	7 - 18 December 1985	Shrimp	32
19	10 - 18 January 1986	Shrimp	27
20	25 January-4 February 1986	Fish	41
21	12 - 22 February 1986	Shrimp	34
22	2 - 11 March 1986	Fish	31
23	18 - 28 March 1986	Shrimp	32
24	2 - 11 April 1986	Fish	22
25	22 April - 1 May 1986	Shrimp	22
26	12 - 21 May 1986	Fish	25
27	1 - 4 June 1986	Fish	7
28	1 - 5 July 1986	Shrimp	9
29	November 1986	Shrimp	N/A
30	2 - 4 December 1986	Fish	26
31	15 - 21 December 1986	Shrimp	N/A
32	January 1987	Shrimp	N/A

Note: N/A = Not available.

less than 20 individuals) the actual number was recorded along with the total weight in order to calculate the average weight of an individual. If the number was greater, samples were usually taken for length frequency measurements; these samples were weighed and used to calculate the average weight.

Density and biomass estimates were obtained using the swept area method. The number of huals in each depth stratum is given in Table 4. For fish trawling, the following inputs were used: the distance between trawl wing tips was 18 m, the average trawlingdistance was 1.3 nm (1.5 miles). For shrimp trawling, the distance between trawl wing tips was 60.8 m (15.2 m x 4), the average trawling distance was about 3 nm and the escapement factor was 50%. Average catch rates were calculated for each stratum. Multiplication with the corresponding stratum area gives the total stratum biomass while the overall biomass was obtained by the summation of each individual stratum biomass.

Estimation of Population Parameters

For the abundant species in the catch, samples of 50 to 200 individuals were randomly selected for length frequency measurements. Total lengths (TL) were measured in cm. Total length of shrimp samples was measured from the tip of the rostrum to the posterior edge of the telson. No length measurements were made for the sea catfish (Family *Ariidae*) and the jewfish (Family *Sciaenidae*) because of inconsistent taxonomic identification of the species.

Length frequency data for four shrimp (*Penaeus monodon, P. semisulcatus, P. merguiensis* and *Metapenaeus monoceros*) and eight demersal fish species (*Saurida tumbil, Upeneus sulphureus, Nemipterus japonicus, Lepturacanthus savala, Pomadasys hasta, Pampus argenteus, P. chinensis* and *Ilisha filigera*) were re-analyzed to obtain the growth parameters L_∞ (asymptotic length) and k (growth constant) of the von Bertalanffy growth formula (VBGF). All the length frequency data were pooled and re-entered using the FiSAT software. To estimate population parameters the ELEFAN I routine (incorporated in FiSAT) was used. The same data were used for the estimation of total mortality (Z), natural mortality (M), and fishing mortality (F), as well as their exploitation ratios. Total mortality was estimated using the length converted catch curve method incorporated as a separate routine in FiSAT. The natural mortality coefficient (M) was estimated using Pauly's empirical formula (Pauly 1980) and the fishing mortality coefficient (F) was derived by subtracting M from Z. The exploitation ratio (E) was then computed as the ratio of F and Z.

Preliminary Surplus Production Modeling

The annual shrimp catch and fishing effort of commercial trawlers from 1981 to 1998 and the annual fish catch and fishing effort of commercial trawlers from 1986 to 2000 were used to estimate the Maximum Sustainable Yield (MSY). The surplus production models described by (Schaefer, 1954 and Fox 1970) were used in the estimation of MSY. The data used for the modeling were taken from trawl catch statistics compiled by the Department of Fisheries.

Table 4. The number of shrimp and fish trawls used in the analyses, by year and depth zone.

Depth zone (m)	Area (km²)	Shrimp trawl			Fish trawl		
		1985	1986	1987	1984	1985	1986
10 - 20	6 861	3	8	9	29	24	7
21 - 50	6 769	22	78	28	48	55	47
51 - 80	5 395	37	49	31	58	44	42
81 - 100	12 315	11	17	1	109	83	45
TOTAL	31 340	73	152	69	244	206	141

[*] The number of hauls in each depth stratum is given in Table 4.

Results and Discussion

Catch per unit effort (CPUE)

The mean catch rates and estimated biomass for shrimps and demersal fish per cruise are given in Tables 5a and 5b respectively. The highest catch rate (mean CPUE) of 16.23 kg•hr^{-1} (corresponding to an estimated shrimp biomass of 3 009 t) was recorded from cruise 14 and the lowest catch rate of 0.22 kg•hr^{-1} (with an estimated biomass of 41 t) was from cruise 23. For demersal fish surveys, cruise 13 had the highest mean catch rate of 630 kg•hr^{-1}, for an estimated demersal fish biomass of 394 597 t. In contrast, cruise 06 had the lowest mean catch rate of only 162.52 kg•hr^{-1}, corresponding to an estimated biomass of only 102 790 t.

Tables 6a and 6b are the overall species composition (by weight and percentage) of shrimp and demersal fish catches (from mean CPUE) for each survey year, respectively. For shrimps, the 1987 survey recorded the highest CPUE at 6.2 kg•hr^{-1} while the lowest was during 1986 at 3.1 kg•hr^{-1}. During shrimp trawling, the perennial component of the catches was the brown shrimp (*Metapenaeus monocerus*), which usually accounted for 38% to 52% of the total shrimp catch. The 1985 fish survey recorded the highest CPUE at 148.1 kg•hr^{-1} while 1984 had the lowest at 127.5 kg•hr^{-1}. Groups with high abundance in trawl catches are the croakers, goatfishes, threadfin breams and hairtails.

Table 5a. Mean catch rate and estimated biomass of shrimp (1985 - 87).

Cruise No.	Mean Catch Rate (kg·hr^{-1})	Biomass (t)
14	16.23	3 009
16	1.68	312
17	4.50	834
18	7.47	1 386
19	6.69	1240
21	3.05	565
23	0.22	41
25	8.54	1 584
28	3.83	710
29	12.35	2 291
31	6.12	1 134
32	7.30	1 355

Table 5b. Mean catch-rate and estimated biomass for fish (1984 - 86).

Cruise No.	Mean Catch Rate (kg·hr^{-1})	Biomass (t)
01	301.28	188 708
02	239.58	150 065
03	203.22	127 303
04	287.96	180 370
05	265.68	166 415
06	162.52	101 790
08	241.20	151 077
09	286.45	179 698
10	165.78	103 838
12	362.70	227 173
13	630.00	394 597
14	380.68	238 447
15	588.96	368 892
16	283.02	177 268
20	206.46	129 312
22	265.84	166 510
24	239.74	150 164
26	285.52	178 842
30	312.22	195 561

Biomass Estimates

Shrimp Biomass

The estimated biomass for penaeid shrimps within the 10 to 100 m depth zone amounts to 1.055 t using a catchability coefficient of 0.5 (Table 7). The most abundant species was the brown shrimp (*Metapenaeus monoceros*), whose estimated biomass of 551 t accounts for more than half of the total penaied shrimp biomass. Next in abundance was the pink shrimp (*Parapenaeopsis stylifera*), which had an estimated biomass of 211 t (20%) and the giant tiger shrimp (*Penaeus monodon*) whose abundance was estimated at 74 t (7%). The highest concentration of *M. monoceros* was found at the 81 to 100 m depth zone, for *P. monodon* it was at the 51 to 80 m depth zone, while for *P. stylifera* it was at the 10 to 20 m depth zone.

Table 6a. Species composition of shrimp trawl catches (1985 - 87).

Species	Year							
	1985		1986		1987		1985 - 87	
	CPUE (kg·hr^{-1})	%	CPUE (kg·hr^{-1})	%	CPUE (kg·hr^{-1})	%	CPUE (kg·hr^{-1})	%
Penaeus monodon	0.40	7.03	0.34	10.93	0.50	8.03	0.40	8.66
Penaeus merguiensis	0.08	1.41	0.02	0.64	–	–	0.03	0.65
Penaeus semisulcatus	0.04	0.70	0.05	1.61	0.31	4.98	0.09	1.95
Metapenaeus monoceros	2.97	52.20	1.32	42.44	2.37	38.04	1.94	41.99
Metapenaeus spinulatus	0.09	1.58	–	–	–	–	0.01	0.22
Parapenaeopsis stylifera	1.14	20.04	0.14	4.50	0.43	6.90	0.34	7.36
Penaeus indicus	–	–	0.04	1.29	0.06	0.96	0.04	0.87
Metapenaeus brevicornis	–	–	0.20	6.43	0.17	2.73	0.13	2.80
Other shrimps	0.97	17.05	1.00	32.16	2.39	38.36	1.64	35.50
TOTAL	5.69	100.00	3.11	100.00	6.23	100.00	4.62	100.00

Table 6b. Species composition of demersal fish catches (1984 - 86).

Species	Year							
	1984		1985		1986		1984 - 86	
	CPUE (kg·hr^{-1})	%	CPUE (kg·hr^{-1})	%	CPUE (kg·hr^{-1})	%	CPUE (kg·hr^{-1})	%
Saurida tumbil	0.78	0.61	2.44	1.65	1.16	0.83	1.26	0.90
Upeneus sulphureus	3.60	2.82	2.36	1.59	2.69	1.92	2.86	2.03
Lepturacanthus savala	3.97	3.11	2.31	1.56	4.21	3.00	3.07	2.18
Nemipterus japonicus	1.54	1.21	1.71	1.15	9.45	6.74	2.49	1.77
Pomadasys hasta	1.88	1.47	0.84	0.57	0.86	0.61	1.22	0.87
Pampus argenteus	1.21	0.95	0.49	0.33	0.80	0.57	0.74	0.53
Pampus chinensis	0.33	0.26	0.14	0.09	0.21	0.15	0.20	0.14
Johnius argentatus	4.12	3.23	0.31	0.21	–	–	0.98	0.70
Harpadon nehereus	0.84	0.66	1.15	0.78	–	–	0.63	0.45
Ilisha filigera	0.70	0.55	0.39	0.26	1.11	0.79	0.62	0.44
Arridae spp.	2.74	2.15	0.49	0.33	–	–	0.80	0.57
Sciaenidae spp.	1.04	0.82	5.71	3.85	3.54	2.53	2.41	1.71
Other fish	104.75	82.16	129.80	87.63	116.18	82.86	123.34	87.71
TOTAL	127.50	100.00	148.14	100.00	140.21	100.00	140.62	100.00

The estimated biomass for penaeid shrimps in 1986 was 577 t for the same catchability coefficient (Table 7). Again, the most abundant species was *M. monoceros* whose biomass of 245 t was roughly 42% of the overall shrimp biomass. *Penaeus monodon* followed at 63 t, equivalent to 11%. Another brown shrimp (*Metapenaeus brevicornis*) came next, whose 37 t amounted to 6% and then the pink shrimp. *P. stylifera* contributed 26 t or roughly 5% of the total biomass. The most abundant concentration of *M. monoceros* was found at the 51 to 80 m depth zone. *P. monodon* had its highest concentration in the 21 to 50 m depth zone while *M. brevicornis* and *P. stylifera* were highest in the 10 to 20 m depth zone.

The estimated shrimp biomass for 1987 was 1 153 t (Table 7). *M. monoceros* contributed 439 t or 38% to the total shrimp biomass while *P. monodon* and *P. stylifera* contributed 93 t (8%) and 79 t (7%), respectively. *M. brevicornis* contributed 32 t or roughly 3% of the total shrimp biomass. *M. monoceros* and *P. monodon* were most abundant in the 21 to 50 m depth zone while *M. brevicornis* and *P. stylifera* were abundant in the 10 to 20 m depth zone.

Analyzing the combined data for the three sampling years (1985 - 87), the average penaeid shrimp biomass amounted to 857 t within the 10 to 100 m depth zone. The highest biomass was in the 21 to 50 m depth zone, followed by the 51 to 80 m depth zone. The biomass levels at 10 to 20 m and in the 81 to 100 m depth zones are almost identical at 173 t and 177 t respectively (Table 7). However, the 81 to 100 m depth zone covers a much larger area.

Based on earlier surveys conducted to estimate standing stock of shrimps in the Bay of Bengal, Bangladesh, the estimates varied from 1 000 t to 11 000 t (Mustafa et al. 1987; Penn 1983; Van Zalinge 1986; West 1973; White and Khan 1985). Penn (1983) and Rashid (1983) reported almost the same standing stock of shrimp at 3 000 t (average), while estimates made by White and Khan (1985) were slightly higher at 3 300 t (average). The shrimp biomass estimated from the trawl surveys has shown a tremendous (about 90%) decline from about 11 000 t in 1973 to only about 857 t in 1985 - 87. However, there are disparities in the number of sampling stations, survey area and differences in collection time, as most trawling operations for the period under the study were done during the daytime.

Demersal Fish Biomass

The estimated biomass for demersal fish within the 10 to 100 m depth zone using a catchability coefficient of 1.0 amounted to 159 725 t in 1984 (Table 8). The highest estimated biomass of 59 746 t was obtained from the 10 to 20 m depth zone. This was followed by the 21 to 50 m depth zone with an estimated biomass of 41 282 t. *Johnius argentatus* recorded the highest biomass from both the 10 to 20 m and 21 to 50 m depth zones, amounting to 3 220 t and 1 944 t, respectively. The sea catfish (Ariidae) was the next most abundant species in the 10 to 20 m depth zone with 2 878 t, while in the 21 to 50 m depth zone it was the hairtail (*Lepturacanthus savala)* with 1 038 t. In the 51 to 80 m depth zone, the most abundant species was the goatfish (*Upeneus sulphureus)* with 1 983 t, followed by *L. savala* with 1 277 t. At the 81 to 100 m depth zone, the most abundant species was *Nemipterus japonicus* (Japanese threadfin bream) with 1 517 t, followed by *U. sulphureus* (1 375 t).

During the trawl survey in 1985, the biomass for demersal fish within the 10 to 100 m depth zone for the same catchability coefficient was estimated at 185 581 t (Table 8). As in 1984, the 10 to 20 m depth zone had the highest estimated biomass at 61 055 t, which is almost one-third of the total fish biomass, followed by the 21 to 50 m depth zone whose estimated biomass was 56 163 t. The sea catfish (Ariidae) had the highest estimated abundance in both the 10 to 20 m and 21 to 50 m depth zones, amounting to 4 835 t and 2 131 t respectively. The bombay duck (*Harpadon nehereus*) was the next most abundant species in the 10 to20 m depth zone with 748 t, while in the 21 to 50 m depth zone, the second most abundant species was the hairtail, *L. savala*. *Upeneus sulphureus* was again the most abundant species in the 51 to 80 m depth zone with 1 380 t followed by the Japanese threadfin bream, *N. japonicus* with 1 113 t. In the 81 to 100 m depth zone, *N. japonicus* had the highest estimated biomass at 800 t, followed again by *L. savala* with 394 t.

The demersal fish biomass within the 10 to 100 m depth zone in 1986 was estimated to be 175 648 t (Table 8). Unlike in the two previous years (1984 and 1985), the 51 to 80 m depth zone now had the highest biomass with 53 742 t followed by the 21 to 50 m depth zone whose estimated biomass stood at 49 577 t. The most abundant species in the 10 to 20 m depth zone was the hairtail, *L. savala*

Table 7. Biomass distribution of shrimps by depth zone estimated from the trawl surveys, Table 4 shows the area of each depth zone and the number of hauls.

Depth zone (m)	1985			1986			1987			1985 - 87		
	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)
10 - 20	5.21	30.80	211	1.36	8.03	55	7.01	41.50	285	4.26	25.18	173
21 - 50	6.37	37.71	255	5.27	31.16	211	18.95	112.11	759	7.84	46.40	314
51 - 80	7.52	44.47	240	6.43	38.05	205	3.50	20.73	112	6.06	35.85	193
81 - 100	4.78	28.27	348	1.45	8.55	105				2.43	14.36	177
TOTAL	5.69	33.65	1 055	3.11	18.40	577	6.23	36.87	1 155	4.62	27.35	857

Table 8. Biomass distribution of demersal fish by depth zone estimated from the trawl surveys, Table 4 shows the area of each depth zone and the number of hauls.

Depth zone (m)	1984			1985			1986			1984 - 86		
	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)	Mean catch rate ($kg \cdot h^{-1}$)	Mean density ($kg \cdot km^{-2}$)	Biomass (t)
10 - 20	435.72	8 708.10	59 746	445.26	8 898.81	61 055	286.26	5 361.24	36 783	411.52	8 224.39	56 428
21 - 50	305.14	6 098.63	41 282	145.16	8 297.11	56 163	366.46	7 324.17	46 577	360.40	7 202.86	48 756
51 - 80	198.92	3 975.63	21 449	319.60	6 387.65	34 461	498.42	9 961.38	53 742	302.84	6 052.32	32 652
81 - 100	151.34	3 024.59	37 248	137.74	2 752.92	33 902	144.42	2 886.34	35 545	155.70	3 111.94	38 324
TOTAL	255.00	5 096.51	159 725	296.28	5 921.55	185 581	280.42	5 604.59	175 648	281.24	5 620.92	176 160

with 2 702 t, followed by the sea catfish (Ariidae) with biomass of 2 586 t. For the depth zone (21 to 50 m), *U. sulphureus* was the most abundant at 2 622 t, followed by *L. savala* at 1 874 t. For the 51 to 80 m depth zone and 81 to 100 m depth zones, the Japanese threadfin bream (*N. japonicus*) exhibited the highest abundance at 3 239 t and 8 130 t, respectively. *U. sulphureus* was the second most abundant species in the 51 to 80 m depth zone with 717 t while in the 81 to 100 m depth zone, the sea catfish (Ariidae) was the second most abundant species with 1 286 t.

Analysis of the combined demersal trawling data for the three sampling years (1984 - 86) gives an estimated fish biomass of 176 160 t (Table 8). Biomass was highest in the 10 to 20 m depth zone and it decreased subsequently (in deeper strata). It is worth noting that within such a short period of time as three years, a very drastic change in demersal fish catch composition can occur. A good example would be the species *J. argentatus*, which was the most abundant species in 1984. It showed a huge decrease in abundance the following year (1985) and then a year later (1986) it was no longer within the list of most abundant species. Other species have emerged as the most abundant replacing the over-exploited ones. Although the results may not be conclusive, such absences (or "disappearances") could be an indication of biological over-fishing. Similar to the biomass trends exhibited by the shrimp resources, the demersal fish biomass also declined by about 30% from 260 000 t in 1973 to 176 000 t in 1984 - 86 (Fig. 2).

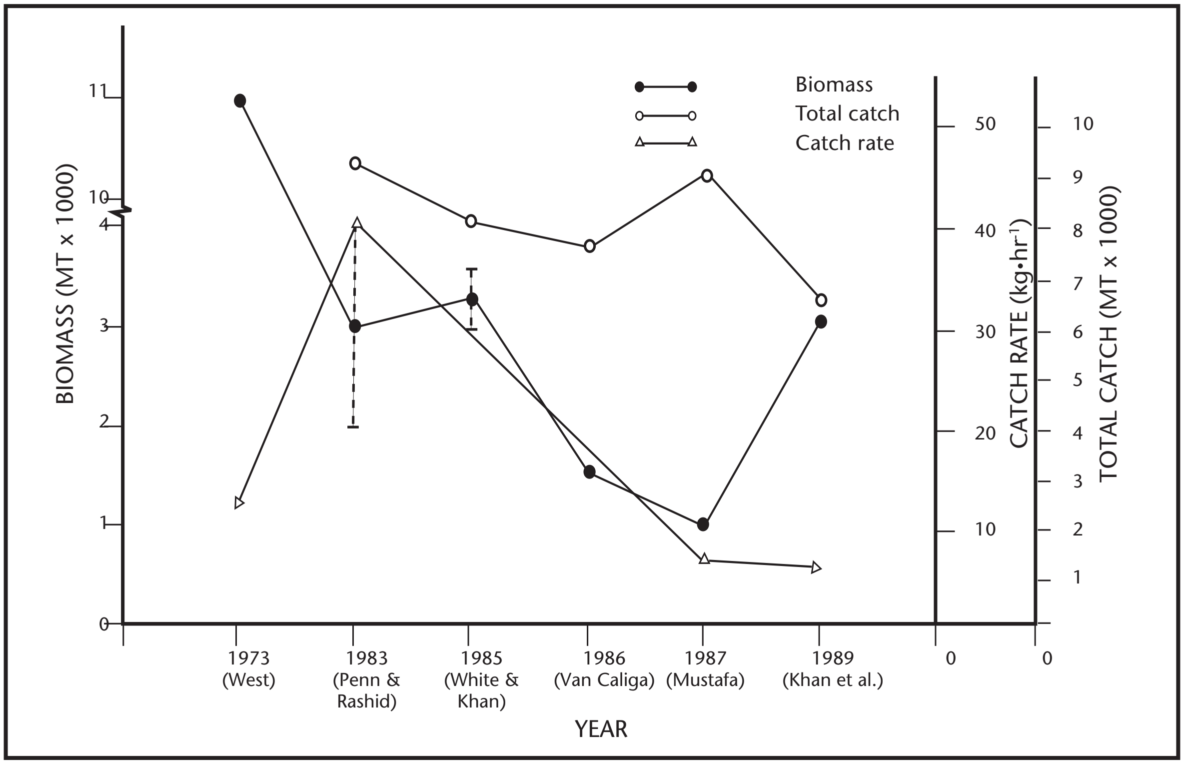

Fig. 2. Yearly biomass, catch rate and total catch of shrimp.

Growth and Mortality Parameters

Aside from looking at standing stock (or biomass), another indicator of the status of the fisheries is the rate of exploitation of targeted (or even untargeted) species. Knowledge of their growth and mortality parameters is essential in establishing whether the stock (or species) is optimally exploited or not. The parameters derived from the present study are presented in Table 9.

Results of the length-frequency analysis for both male and female *P. monodon* resemble the population and mortality parameters estimated by Khan et al. (1994) using data collected during the period 1988 - 89. For *P. semisulcatus*, there was a considerable difference between the asymptotic lengths for males and females, utilizing the same procedure, although similar fishing pressure on *P. semisulcatus* applied to the results of Mustafa (1999).

The male and female populations of the banana shrimp (*P. merguiensis),* were studied separately. Results show that the estimated parameters for females are higher than for males. The E values were estimated to be 0.68 and 0.47 for males and for females, respectively. The estimated growth parameters for the brown shrimp (*M. monoceros)* were similar to the results observed by Khan et al., (1994). The exploitation ratios were 0.58 and 0.47 for males and females, respectively. These estimates bear some resemblance to the results found by Mustafa (1989).

The growth parameters for the lizardfish (*S. tumbil*) estimated using ELEFAN I were similar to the estimates made by Mustafa and Khan, (1988). The present estimates of total (Z), natural (M) and fishing (F) mortalities, as well as the exploitation ratio (E) were also similar to the results found by Mustafa and Khan, (1988). For the goatfish (*U. sulphureus)*, the present growth estimates resemble the results of the study by Mustafa (1993a) while estimates of mortality and exploitation ratios closely resemble the results observed by Mustafa (1999). The growth estimates computed for the Japanese threadfin bream (*N. japonicus)*, were similar to those estimated by Khan and Mustafa (1989). The rates of total (Z), natural (M) and fishing (F) mortalities of *N. japonicus* were also similar to the estimates of Khan and Mustafa (1989) although the exploitation (E) value was a little higher.

Table 9. Growth and mortality parameters for selected trawl-caught demersal fish and shrimp species in Bangladesh waters (1984 - 87) (M = male, F = female).

Species	Asymptotic Length (cm) (L_∞)	Growth Constant (k)	Mortality Rate (Annual)			Exploitation Rate (E)	M/K	Lc/$_\infty$	Probability of Capture		Spawning Time	
			Natural (M)	Fishing (F)	Total (Z)				L_{50}	L_{75}	Winter Cohort	Summer Cohort
A. SHRIMP												
Penaeus monodon (M)	29.0	1.29	2.13	5.93	8.06	0.74	1.65	0.71	20.57	21.51	February	September
P. monodon (F)	32.5	1.2	1.97	2.68	4.65	0.58	1.64	0.69	22.54	23.82	February	September
P. semisulcatus (M)	24.7	1.36	2.31	5.41	7.72	0.70	1.69	0.63	15.47	16.29	January	August
P. semisulcatus (F)	25.6	1.28	2.19	3.81	6.00	0.63	1.71	0.77	19.69	20.76	January	September
P. merguiensis (M)	17.92	1.235	2.37	5.01	7.38	0.68	1.92	0.80	14.36	15.13	January	June
P. merguiensis (F)	22.10	1.299	2.31	2.03	4.34	0.47	1.78	0.80	17.69	18.59	February	July
Metapenaeus monoceros (M)	17.50	1.40	2.59	3.52	6.11	0.58	1.85	0.54	9.37	10.15	April	October
M. monoceros (F)	18.0	1.32	2.47	2.17	4.64	0.47	1.87	0.62	11.23	12.06	April	October
B. FISH												
Saurida tumbil	40.70	0.635	1.22	0.71	1.93	0.37	1.92	0.49	19.96	21.27	–	June
Upeneus sulphureus	22.40	1.40	2.41	4.71	7.12	0.66	1.72	0.41	9.12	9.92	–	May
Nemipterus japonicus	26.50	1.04	1.90	1.96	3.86	0.51	1.83	0.38	10.19	11.16	–	June
Lepturacanthus savala	105.35	0.68	0.98	1.05	2.03	0.52	1.44	0.26	27.91	32.68	February	–
Pomadasys hasta	57.0	0.40	0.82	0.67	1.49	0.45	2.05	0.77	44.16	46.19	–	May
Pampus argenteus	28.0	0.63	1.35	1.38	2.73	0.51	2.14	0.81	22.61	23.60	–	August
P. chinensis	38.0	0.70	1.32	2.17	3.49	0.62	1.88	0.66	25.25	26.07	January	–
Ilisha filigera	41.10	0.63	1.21	0.71	1.92	0.37	1.92	0.39	15.91	16.92	–	June

For the ribbonfish (*L. savala)* the L_∞ and k values were similar to those reported by Khan et al., (1994) using length frequency data collected during 1988 - 89. The mortality estimates, however, were similar to those estimated by Mustafa (1999), although the exploitation ratio was lower. Estimates of growth parameters for the white grunter (*P. hasta)*, were almost the same as the estimated values derived by Mustafa and Azadi (1995). The mortality estimates as well the exploitation rates of the present study, however, were similar to those reported by Mustafa (1999).

For the silver pomfret (*P. argenteus)*, the estimated values of L_∞ and k were the same as the values reported by Mustafa (1993b), utilizing length frequency data collected in 1986. Though estimated instantaneous rates of total, natural and fishing mortalities for *P. argenteus* do not resemble any of those reported by other authors, the exploitation ratio was similar to the derived estimate of Khan et al., (1997). The estimated growth parameters of the Chinese pomfret (*P. chinensis)* show close similarity with the results observed by Mustafa (1999), but the estimated values of total, natural and fishing mortalities of *P. chinensis* were all higher than those reported by Mustafa (1999), together with the exploitation ratio. The estimated L_∞ value for the big-eye Ilisha, *Ilisha filigera* (L_∞ = 41.1 cm) was bigger than that derived by Mustafa (1999) although the value of k (0.63 $year^{-1}$) was lower. The mortality rates obtained were lower, including the exploitation ratio as compared to the values reported by Mustafa, (1999).

The ratio of exploited species compared to under-exploited species differs in the present study compared to literature values for the same region. The disparity could be explained by the different computation procedures, or differences in computational adjustments such as correction for gear selectivity. Since the derived parameters were not subjected to the same computational procedures, the exploitation rates in their present form cannot be used forcomparing prevailing conditions during their respective periods. Nevertheless, it is evident that since the preferred (or targeted) species are shrimps, their exploitation rates on the average are much higher than those of the demersal fish. Since the rate of exploitation (E) is the ratio of fishing mortality to total mortality, it follows that those species with high E values are the same species exhibiting high fishing mortality values.

Tables 10 and 11 give the compiled growth and mortality parameters for shrimps and demersal fish respectively. The E value based on the compiled parameters for shrimps is 0.61 (Fig. 3) while for demersal fish it is 0.57 (Fig. 4), both above the optimal exploitation value of 0.50; thus indicating that the demersal resources in the study area are over-exploited and confirming the declining trend in demersal biomass noted earlier.

Surplus Production Models

The annual shrimp catch and fishing effort of trawlers from 1981 to 1998 and the annual fish catch and fishing effort of trawlers from 1986 to 2000 are shown in Tables 12a and 12b. During the last one and a half decades, the total effort of the shrimp trawl fishery was within the range of around 5 000 - 6 000 standard fishing days, producing 3 500 - 6 000 t of shrimps. Earlier reports estimated the MSY for penaeid shrimps at 7 000 t with optimum effort at around 7 000 - 8 000 standard fishing days. However, Mustafa and Khan (1993) on the basis of surplus production models, estimated the MSY for shrimps to be within 4 100 to 4 300 t at effort levels of 8 500 to 11 000 fishing days. Nonetheless, recent statistics yield a different set of estimated values for MSY and optimum effort.

The surplus production models of Schaefer (1954) and Fox (1970) were used to estimate the MSY for shrimps using the catch and effort data presented in Table 12a. These data were taken from trawl catch statistics compiled by the Department of Fisheries. The MSY value for penaeid shrimps using the Schaefer model was 3 566 t corresponding to an optimum effort level (f_{msy}) of 6 483 standard fishing days. Using the Fox model, the MSY for shrimps was estimated to be 3 474 t at an optimum effort level of 6 456 fishing days. Three data points corresponding to the years 1981-82, 1983-84 and 1984-85 were not included in the computation for MSY and f_{msy} values since the estimated effort values during those years were considered unreliable by Mustafa and Khan, (1993). The correlation coefficients were 0.30 and 0.269 for the Schaefer and Fox models, respectively. Similar analysis undertaken for demersal fish catches exhibited extremely poor correlation between catch rates and effort values. This was probably due to error estimates in the discarded by-catch, so the results were not considered.

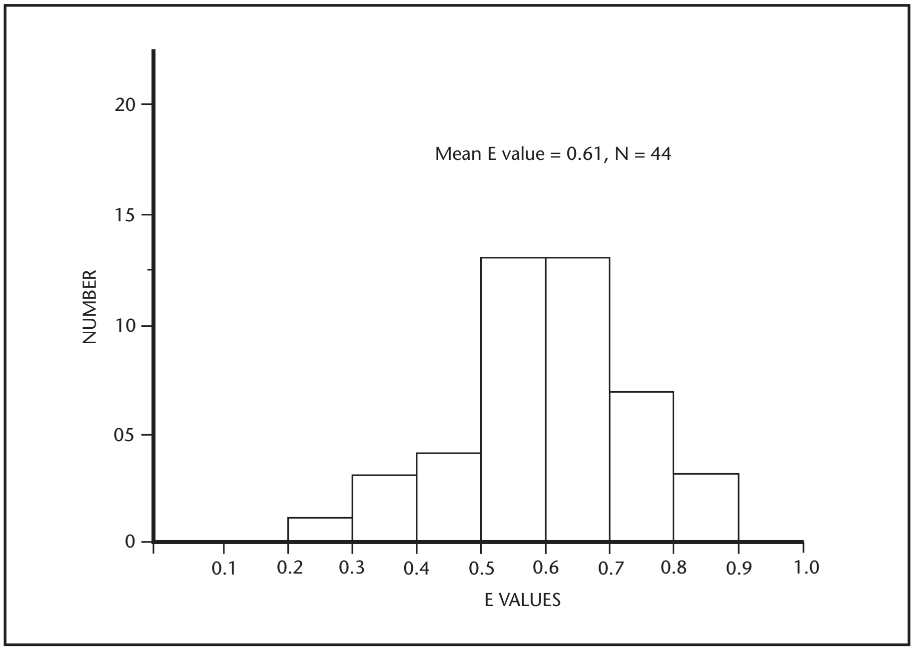

Fig. 3. Distribution of compiled E values of different shrimp species.

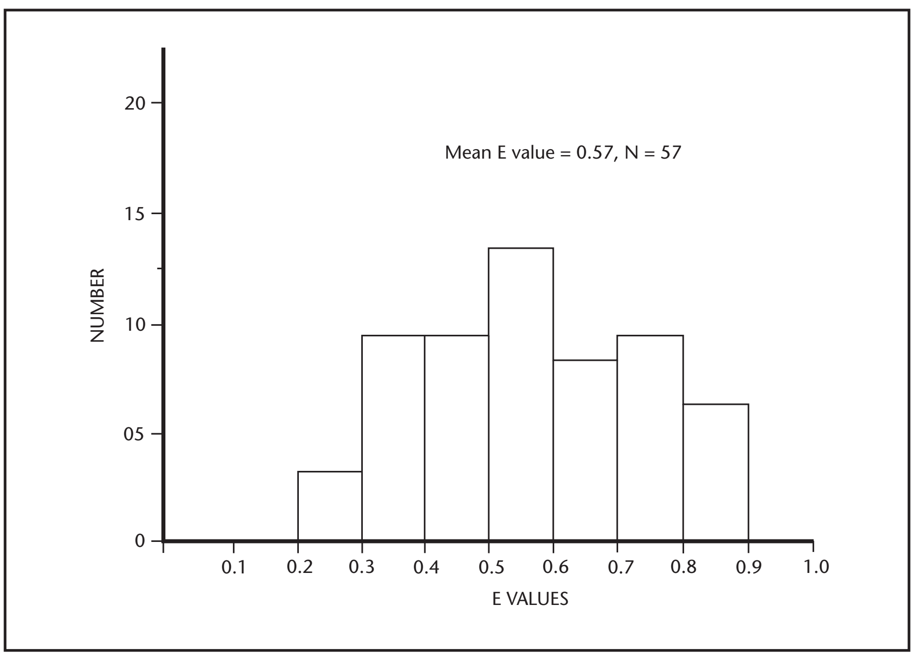

Fig. 4. Distribution of compiled E values of different fish species.

Table 10. Compilation of growth and mortality parameters, from previous studies of some marine shrimp species exploited by the trawl fishery in Bangladesh (M = male, F = female).

Species	Asymptotic Length (cm) (L_∞)	Growth Constant (k)	Mortality Rate (Annual)			Exploitation Rate (E)	M/K	Lc/L_∞	L_{75}	References
			Natural (M)	Fishing (F)	Total (Z)					
Penaeus monodon (M)	30.50	1.14	1.94	4.89	6.83	0.71	1.70	0.57	17.5	Mustafa and Khan (1989)
P. monodon (F)	31.50	1.35	2.14	3.58	5.72	0.62	1.59	0.50	15.7	-do-
P. monodon (M)	30.10	1.00	1.89	3.15	5.04	0.63	1.89	0.64	19.38	Khan et al. (1989)
P.monodon (F)	31.30	1.21	2.00	6.38	8.38	0.76	1.65	0.78	24.51	-do-
P. monodon (M)	28.80	1.20	2.03	5.86	7.89	0.74	1.69	0.61	17.50	Khan et al. (1994)
P.monodon (F)	30.50	1.70	2.50	3.28	5.78	0.57	1.47	0.51	15.70	-do-
P. monodon (M)	30.00	0.94	1.72	3.33	5.05	0.66	1.83	–	–	Mustafa (1999)
P.monodon (F)	32.10	0.97	1.72	2.13	3.85	0.55	1.77	–	–	-do-
P. semisulcatus (M)	23.50	0.80	1.73	3.47	5.20	0.67	2.16	–	–	Mustafa (1999)
P.semisulcatus (F)	27.00	0.90	1.72	2.98	4.70	0.63	1.91	–	–	-do-
Metapenaeus monoceros (M)	16.20	1.40	2.64	4.90	7.54	0.65	1.89	0.66	10.68	Khan et al. (1989)
M. monoceros (F)	19.60	1.45	2.56	5.10	7.66	0.67	1.77	0.59	11.64	-do-
M. monoceros (M)	15.70	1.60	2.91	2.98	5.89	0.51	1.82	0.76	11.93	Mustafa (1989)
M. monoceros (F)	18.50	1.65	2.84	1.68	4.52	0.37	1.72	0.79	14.63	-do-
M. monoceros (M)	18.00	1.40	2.80	2.41	5.21	0.54	2.00	0.49	8.90	Khan et al. (1994)
M. monoceros (F)	18.60	1.60	2.70	3.58	6.28	0.55	1.69	0.51	9.50	-do-
M. monoceros (M)	16.50	1.50	2.75	3.68	6.43	0.57	1.83	–	–	Mustafa (1999)
M. monoceros (F)	19.40	1.52	2.65	3.94	6.59	0.60	1.74	–	–	-do-

Table 11. Compilation of growth and mortality parameters from previous studies of some demersal fish species exploited by the trawl fishery in Bangladesh.

Species	Asymptotic Length (cm) (L_∞)	Growth Constant (k)	Mortality Rate (Annual)			Exploitation Rate (E)	M/K	L_c/L_∞	L_{75}	References
			Natural (M)	Fishing (F)	Total (Z)					
Saurida tumbil	39.0	0.64	1.66	0.88	2.54	0.35	2.59	0.46	18.02	Mustafa and Khan (1988)
S. tumbil	41.8	0.95	1.57	1.42	2.99	0.47	1.65	–	–	Mustafa (1999)
Upeneus sulphureus	20.87	1.45	2.40	9.10	11.50	0.79	1.66	–	–	Khan et al. (1987)
U. sulphureus	20.35	1.23	2.28	6.36	8.64	0.74	1.85	0.52	10.61	Khan et al. (1989)
U. sulphureus	22.0	1.10	2.07	9.45	11.52	0.82	1.88	0.50	11.07	Mustafa (1993a)
U. sulphureus	22.70	0.98	1.91	3.86	5.77	0.67	1.95	–	–	Mustafa (1999)
Nemipterus japonicus	24.16	1.06	1.97	1.08	3.75	0.47	1.86	–	–	Khan and Mustafa (1989)
N. japonicus	26.50	0.60	1.32	3.93	5.25	0.83	2.20	–	–	Humayun et al. (1989)
N. japonicus	24.50	0.94	0.78	0.55	1.33	0.41	0.83	–	–	Mustafa (1994)
N. japonicus	25.60	0.94	1.79	2.58	4.37	0.59	1.90	–	–	Mustafa (1999)
N. japonicus	27.20	0.92	1.74	0.51	2.25	0.23	1.89	–	–	Ashraful (1998)
Lepturacanthus savala	105.0	0.85	1.33	0.73	2.06	0.35	1.56	0.38	40.05	Khan et al. (1994)
L. savala	106.50	0.80	1.08	0.81	1.89	0.43	1.35	–	–	Ashraful (1998)
L. savala	108.00	0.75	1.04	1.54	2.58	0.60	1.39	–	–	Mustafa (1999)
Pomadasys hasta	54.83	0.39	0.77	0.78	1.55	0.51	1.97	–	–	Khan et al. (1985)
P. hasta	56.90	0.38	0.79	0.82	1.61	0.51	2.08	–	–	Mustafa and Azadi (1995)
Pampus argenteus	28.00	0.63	1.35	0.28	1.63	0.17	2.14	–	–	Mustafa (1993b)
P. argenteus	30.50	1.66	2.35	2.90	5.25	0.55	1.42	–	–	Khan et al. (1997)
P. argenteus	29.80	0.53	1.18	0.79	1.97	0.40	2.23	–	–	Mustafa (1999)
P. chinensis	38.10	0.67	1.29	0.83	2.12	0.39	1.92	–	–	Mustafa (1999)
Ilisha filigera	32.50	0.90	1.63	1.25	2.86	0.44	1.81	–	–	Ashraful (1998)
I. filigera	35.00	0.75	1.42	1.95	3.37	0.58	1.89	–	–	Mustafa (1999)

Table 12a. Annual shrimp catch and fishing effort of trawlers (1981 - 98).

Year	Standard effort (days)	Shrimp catch (t)	Catch per unit effort ($kg \cdot day^{-1}$)
1981 - 82	3 782	1 697	449
1982 - 83	7 024	3 120	444
1983 - 84	9 662	5 461	565
1984 - 85	8 159	5 518	676
1985 - 86	6 444	4 034	626
1986 - 87	6 928	4 488	648
1987 - 88	6 583	3 523	535
1988 - 89	6 945	4 893	705
1989 - 90	5 546	3 134	565
1990 - 91	4 499	3 430	762
1991 - 92	6 122	2 902	474
1992 - 93	7 065	4 188	593
1993 - 94	7 169	3 480	485
1994 - 95	6 761	2 416	357
1995 - 96	7 394	3 588	485
1996 - 97	7 107	3 536	497
1997 - 98	7 491	2 444	326

These results for shrimp catches indicate that the current levels of exploitation are not sustainable and that the fishing effort exerted should be decreased by at least 13.5% to attain sustainability. The 1987 - 88 fishing effort level is the one very close to the optimum level needed to attain MSY. Moreover, considering that only 45 - 49 trawlers were operating during the period of study (1984 - 87) and there are 69 trawlers currently operating, it is suggested that the present fleet should not be increased by the addition of new vessels, so that the proper and rational management of marine fishery resources in Bangladesh can be implemented.

Table 12b. Annual fish catch and fishing effort of trawlers (1986 - 2000).

Year	Standard effort (days)	Fish catch (t)	Catch per unit effort ($kg \cdot day^{-1}$)
1986 - 87	432	1 433	3 318
1987 - 88	846	1 535	1 814
1988 - 89	606	973	1 605
1989 - 90	792	2 105	2 658
1990 - 91	5 116	5 067	990
1991 - 92	900	1 868	2 075
1992 - 93	1 312	6 121	2 119
1993 - 94	1 018	2 723	2 675
1994 - 95	1 083	4 404	4 067
1995 - 96	1 146	4 568	3 986
1996 - 97	1 325	5 793	4 373
1997 - 98	1 485	7 515	5 060
1998 - 99	1 709	1 299	760
1999 - 00	2 014	2 987	1 187

Summary and Conclusion

On the basis of data collected from 1984 - 87 the estimated demersal fish biomass was 176 160 t which was in close proximity to the value presented by Lamboeuf (1987) i.e. 157 000 t (on average). The estimated penaeid shrimp biomass was only 857 t and is much lower than the estimate made by Khan et al. (1989) i.e. 3 100 t. The current estimate is limited by the area covered by the study and the sample size.

The present study reveals that the majority of the penaeid shrimps have been over-fished, except for the females of *P. merguiensis* and *M. monoceros*, whose exploitation ratios were lower than the optimum level. For the demersal fish species only three out of eight species examined did not exceed the optimum level of exploitation. Combining the estimated E values from the present study with those reported by other authors, the average value is beyond the optimum level of exploitation.

The number of trawling vessels operating in Bangladesh since the period of study (1984 - 87) has increased considerably. From 49 shrimp and fish trawlers combined, the present number now stands at 69 trawling vessels. Therefore, it can be safely assumed that other species of fish and shrimps are now over-exploited. So no additional trawlers should be allowed to operate if proper and sound management of the marine fishery resources is to be implemented.

Another matter that needs serious consideration is the discarding of trash fish in the sea. It is a well-known fact in the industry that fish of lower price (mostly fresh fish) are thrown into the sea by trawler operators in order to maximize storage of commercially important fish and shrimps on board. As per Marine Fisheries Ordinance 1983, each shrimp trawler is required to bring 30% of its total catch of white fish to the shore, but operators are not complying. This provision should be strictly enforced. The utilization of mother vessels for collecting the trash fish from trawlers at sea (as discussed in a forum by the Ministry of Fisheries and Livestock and the Directorate of Fisheries) should be looked into.

There is a government order regarding the cessation of fishing operations by trawlers from mid-January to mid-February in order to enable the spawners to breed in the open sea. This order should be applied.

Allowing the irrational development of marine fisheries has resulted in the decline of fish and shrimp stocks. It is a common occurrence that a single stock of fish or shrimp is harvested by a number of different fisheries at different stages of their life cycle. Hence over-fishing in one fishery has affected the others. A classic example is the push net fishery for post larvae of the tiger shrimp (*P. monodon*) and the estuarine set bag net (ESBN) and beach seine fisheries for their juveniles. These methods have been identified as destructive. These fisheries restrict recruitment to the industrial fishery, and result in the lowering of catch rates and overall production. To reverse this alarming situation, particularly for the penaeid shrimp larvae inhabiting the coastal and estuarine waters, fishing gear destructive to shrimp and fish larvae must be banned.

The push net fishery is not only the means of livelihood for the particular community concerned. Some fishers and villagers operate these nets periodically as an alternative source of income. In contrast, a number of coastal fisherfolk largely depend on ESBN and beach seines for their livelihood. An alternative solution might be gradual withdrawal from this fishery and subsequent engagement in other income generating activities. Awareness and motivation amongst the fishers regarding the harmful effects of the gear concerned is lacking.

The day is not far-off when artisanal fishers will hardly catch anything. Therefore, proper conservation and management of the resources are essential. This situation warrants research on the sustainability of resources and biological studies on the stocks (stock assessment). Detailed accounts of fishing activities and the gear operating therein are also crucial for fishery managers. The generation of information would then translate into management plans and actions supportive and beneficial to the fisheries.

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